DOCTORAL THESIS INFORMATION PAGE

Thesis Title: **Investigation of Detection and Error-Correction Decoding with Superposition Modulation for Large-Scale MIMO Systems Using Low-Resolution ADCs**

Major: Telecommunications Engineering

Code: 9.52.02.08

PhD. Candidate: **Hoang Anh Duc**

Scientific Supervisors:

1. Assoc. Prof. Nguyen Trung Hieu

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Training Institution: Posts and Telecommunications Institute of Technology

NEW CONTRIBUTIONS OF THE THESIS:

The thesis aims to investigate and analyze the potential combination of superimposed modulation and P-LDPC codes in large-scale MIMO systems employing low-resolution ADCs. The research focuses on analyzing the problem and constructing a mathematical model suitable for the system's nature, followed by verification through computer simulations to evaluate accuracy and practical applicability. Alongside theoretical analysis, the thesis develops a simulation system in C++ and utilizes the Monte-Carlo method to assess performance in scenarios approximating real-world operating conditions. This approach allows for verifying the alignment between theoretical and simulation results, while evaluating the stability and efficiency of the proposed solution under various configurations and operating modes. The thesis has two main contributions:

The first contribution is proposing an integrated model of superimposed M-QAM modulation with P-LDPC codes in large-scale MIMO wireless communication systems using low-resolution ADCs. Based on this, the thesis evaluates the comprehensive performance of the system, including error resilience, decoding convergence, and spectral efficiency under coarse quantization conditions. Analysis and simulation results show that the signal superimposed modulation scheme with equal weights outperforms the equal-distance scheme in terms of BER performance, particularly in systems using low-resolution ADCs. This approach simultaneously exploits the advantages of superimposed modulation to increase transmission efficiency, while combining it with the robust coding capability of

P-LDPC to improve reliability in hardware-constrained environments.

The second contribution is proposing an improved PEXIT algorithm to analyze and predict decoding thresholds to enhance the performance of large-scale MIMO wireless communication systems using mixed-resolution ADCs at the receiver. The flexible combination of high- and low-resolution ADCs not only significantly reduces power consumption and hardware costs but also maintains signal detection and decoding performance close to that of traditional systems using high-resolution ADCs. Simulations also demonstrate that large-scale MIMO systems achieve superior performance when using a mixed-ADC configuration compared to scenarios where all receiving branches use the same resolution level. Combining multiple ADC resolution levels helps exploit the advantages of each converter type, optimizing the trade-off between energy consumption and BER performance, thereby significantly improving overall system quality.

APPLICATIONS, PRACTICAL APPLICABILITY, OR OPEN ISSUES FOR FURTHER RESEARCH:

While the thesis has achieved several notable results, there are still some limitations that need to be addressed in subsequent studies. These topics all relate to exploiting P-LDPC codes in systems using mixed-resolution ADCs and hold significant potential for expansion in both academic and applied aspects. Specifically, some noteworthy directions are recommended as follows:

(1.) Theoretical research focuses on optimizing the allocation ratio between antennas using low-resolution ADCs and those with high resolution. Initial simulation results yield positive signals; however, further in-depth research is needed to quantitatively analyze the trade-off relationship between Energy Efficiency (EE) and Spectral Efficiency (SE). Furthermore, determining an optimal mixed ratio between antenna types is necessary to achieve the best overall system performance, balancing energy savings and transmission quality.

(2.) Research focuses on constructing and designing P-LDPC codes compatible with each distribution ratio between low- and high-resolution ADC antennas. The goal is to adjust the degree of variable nodes in the base matrix to suit the quantization characteristics of each antenna group, thereby contributing to enhanced system performance. Researching and optimizing P-LDPC codes specifically for Mixed-ADC configurations remains a gap

in the international research community.

(3.) Through the analysis results in Chapter 2 and Chapter 3 and previous studies, it can be observed that the performance of large-scale MIMO communication systems tends to degrade significantly when using a configuration with a ratio of transmit antennas to receive antennas less than 1 ($M/N < 1$), compared to a configuration with the same number of transmit antennas but a different ratio. Determining the optimal ratio between the number of transmit and receive antennas plays a crucial role in the design and deployment process of modern wireless communication systems. This is a highly potential open research direction, promising to yield valuable results in developing signal processing techniques adaptive to the hardware constraints of future wireless systems.

Confirmation of representative Scientific supervisor	**PhD. Candidate**
Assoc. Prof. Le Nhat Thang	**Hoang Anh Duc**